Standardization of Some of the Common Tests Used in Determining the Acuteness of Vision of School Children

BY

J. M. McCALLIE

TRENTON, N. J.

A Thesis Submitted to the Faculty of the Graduate School of the University of Pennsylvania in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy

STANDARDIZATION OF SOME OF THE COMMON TESTS USED IN DETERMINING THE ACUTENESS OF VISION OF SCHOOL CHILDREN

BY

J. M. McCALLIE

TRENTON, N. J.

A Thesis Submitted to the Faculty of the Graduate School of the University of Pennsylvania in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy

June, 1912.

STANDARDIZATION OF SOME OF THE COMMON TESTS USED IN DETERMINING THE ACUTENESS OF VISION OF SCHOOL CHILDREN

Most, if not all of the tests, both letters and characters, used for testing the acuteness of school children are based, in theory, at least, upon the Snellen test letters.

Since the Snellen letters will be referred to often, a brief account of their origin and structure is here given:

In 1862, Dr. Herman Snellen, professor of ophthalmolgy in the University of Utrect, Holland, and director of the Netherlands Institute for Diseases of the Eyes, published an improved series of test types for measuring the acuity of vision.* The principle which guided him in the construction of these test letters is based upon the fact that the normal eye can just discern objects that subtend a one minute angle, the vertex of the angle being the point where the rays of light cross before falling on the retina.

In order that a letter may be recognized each one its elements must be discernible, hence, each of these elements must have a diameter equal to the tangent of an angle of at least one minute. In constructing uniform letters in conformity with this principle, Snellen found that each letter must have at least one diameter equal to the tangent of a five-minute angle. Each letter is therefore made in a square which is subdivided into twenty-five equal squares, each small square being equal in diameter to the tangent of a one-minute angle. Since the tangent of a five-minute angle is equal to 0.001454, to obtain the longest diameter of a letter to be seen at a given distance, Snellen multiplied the length of the tangent of five minutes by the distance, in centimeters, of the letter from the nodal point of the eye; thus, at a distance of one-hundred centimeters the height of the letters should be 0.1454 centimeter, and each stroke of the letter should be at least one-fifth of this, or 0.0291 in length.

Before beginning the work a large number of test cards were collected from different dealers. On some of these were lines of letters of different sizes, on others, lines of pictures or characters of different sizes. Under each one of these lines of different sized letters, pictures, or characters, was printed the distance at which they were supposed to be seen by the normal eye. An examination of this col-

---

*Snellen, H. Optotypi ad visum determinandum secundum formularum $V = \frac{d}{D}$ Ed. XVII. (Probebuchstaben zur Bestimmung der Sehscharfe.) Berlin, H. Peters. 1904.

lection of material soon disclosed the fact that there was no uniformity either in the size, style, or structure of the letters or characters or pictures, gotten out by different houses, which were supposed to be seen at the same distance by the normal eye. Not only was there a lack of uniformity, but, not on a single card, could there be found a set of letters or characters or pictures whose proportions were in accordance with the Snellen measurements. And, not only were these out of proportion, according to Snellen, but they were not of the right size to be seen at the different distances. The letters and characters intended to be read at the shorter distances were generally printed so poorly as to make them useless as tests. Add to these faults the facts, that these letters and characters were printed in black on several shades of white or cream colored cardboard or different shades of white letters on black cards, and, that the finish of the cardboard varied from a glossy white or black to a lustureless white or black, and it can readily be seen that there could be no uniformity of results, to say nothing of accuracy or the possibility of selecting any one of these measures for a standard. It was evident, therefore, that if my work was to have any value, new letters must be made. This was done by most accurately drawing the letters according to the Snellen dimensions from which new and accurate type were made, and, from which, the letters used in these tests were printed, except the tests made in comparing the relative visibility of the "illiterate E," with the 16 ft. letters.

The picture tests were discarded because they were not and could not be constructed according to the Snellen measurements, consequently the results obtained could not be compared with results obtained by tests made with the Snellen letters.

The tests made were divided into two parts. The first had to do with the visibility of the "illiterate E," supposed to be seen by the normal eye at no greater distance than 16 ft., as compared with the visibility of the Snellen letters constructed to be seen by the normal eye at no greater distance than 16 ft.

The second part had to do with determining whether tests made by the Snellen 12 ft., or 16 ft. letters, or a dot,

supposed to be seen at 20 ft., are not as accurate as tests made with letters to be seen 50 ft., 40 ft., 30 ft., or 20 ft.

The following is a detailed description of the method and results obtained by comparing the visibility of the "illiterate E" with the Snellen test letters of the same dimensions:

As stated above, types for the 16 ft. "illiterate E" and the 16 ft. letters were not made anew. This was not necessary because a copy of Snellen's classic work on test types was found which contained the "illiterate E" and the letters of the desired size. The letters taken from this book were O, L, N, Z, B, D, T, and E, and the "illiterate E" turned up, down, right, and left, (see Fig. 1) all of which were supposed to be visible to the normal eye at 16 ft. These were printed on white unglazed paper about the thickness of ordinary book paper.

The 16 ft. letters and the 16 ft. "illiterate E," were selected of one and the same size to enable comparison of results to be made more readily and because the size of the rooms in which the tests were made would not admit of using larger letters.

Each one of these letters and "illiterate E's," were carefully cut out, and pasted on white unglazed cards, three and one-half by six inches, one and one-half inch from the top of the card and equally distant from the sides, one letter or one " illiterate E" on a single card. On the back of each card was written the same letter or "illiterate E" that appeared on the front. This was for the purpose of enabling the operator to know the letter or to tell which way the "illiterate E," was turned, when presented to the subject.

By having the letters on separate cards, so that only one letter was in view at a time, the operator could be sure that the pupil's reply was a judgment on that letter and not on some other letter, as often happens when several letters are shown at one time. This arrangement, also, made it possible to vary the order of presentation, and, so prevent the letters from being memorized. The operator by this device was left free to give his entire attention to the efforts put forth by the children in reading the letters. By holding the cards in his hands, the operator was enabled

to utilize the best light in the room more easily than if he had used a large card hung on the wall, as is usually done in such tests.

The best position for exhibiting the letters, so far as light was concerned, was selected, and, beginning with this position, short chalk marks were made on the floor every two feet the entire length of the room, the first mark being two feet away from the position selected for best light, the second four, and so on.

Everything being ready, the pupils were called one at a time and told to stand with their toes to line twenty, with a card held over one eye. Two or three letters were presented. If the pupil could not read them, he was asked to step up two feet and try again. If he failed again, he was asked to step up two more feet and try again. If he failed at this distance—sixteen feet—he was asked to step up one foot at a time, after each succeeding failure, until he was able to read at least five consecutive letters correctly. The letters were not exposed to view longer than two seconds. If the correct names of five consecutive letters could not be read in the time limit, the result was counted a failure, until a distance was found where the letters could be read. If the subject could read all the letters correctly at sixteen feet, this fact was indicated by placing the fraction 16/16 opposite his name on the record sheet. If he could read the letters only at six feet, this fact was indicated by the fraction 6/16. If the letters could be read at twenty-four feet, this fact was represented by the fraction 24/16, etc.

Having determined the greatest distance at which one eye could read the letters, the same process was repeated with the other eye. Immediately after each pupil was tested with the alphabet cards he was tested with the "illiterate E," cards, by the same general method, except that instead of naming the character the pupil was required to point in the direction, up, down, right, or left, thus indicating the direction of the opening of the E. In this case, as with the letters, a single error was taken to indicate that the pupil's vision was not sufficiently acute to read the characters at that particular distance, and he was required to move toward the cards until he reached the point at which at least

five consecutive characters could be read correctly within the allotted time of not more than two seconds each.

In doing this work the tests with the "illiterate E," always followed the test with the letters, so, if fatigue played any part in the tests it would show itself in the results obtained with the "illiterate E."

Before beginning the test each day, the operator tested his own vision to see whether the light was satisfactory. Tests were made only on days when the light was good. No work was done on cloudy or dark days. These tests were carried on in the different class-rooms, and, so far as each pupil was concerned the test with the "illiterate E," and the letters were made under exactly the same conditions.

470 children took the tests during the months of April and May.

The results of these tests are presented in the table I. This shows the number of eyes tested in grades I to VIII, with the greatest distances at which the alphabet and illiterate characters could be distinguished, Four hundred and seventy pupils, or 940 eyes, were tested. These pupils were distributed throughout the grades as follows: 72 in the first grade, 54 in the second, 39 in the third, 28 in the fourth, 41 in the fifth, 29 in the sixth, 130 in the seventh and 77 in the eighth. The 344 pupils in grades III to VIII, inclusive, were tested with both the alphabet and illiterate characters. In columns headed Totals II to VIII, may be found the figures affording the most ready comparison of the results with the alphabet characters, and illiterate cards. Thus, with the alphabet characters, the largest number of eyes, 148, distinguished the letters at fourteen feet; the next largest 128, at sixteen feet, and the next largest 114, at twelve feet. Of these 688 eyes tested, 390, or 56.7 per cent., distinguished the letters at from twelve to sixteen feet. With the illiterate cards, however, these same eyes distinguished the "illiterate E" at a much greater distance, in fact, 94 pupils saw the "illiterate E," at twenty-two feet. This was the largest number seeing this character at any distance, and the next largest number, 92, saw it at twenty-four feet. The next largest number, 86, saw it at twenty feet. The results of this comparative test with two characters are graphically exhibited in Graph I. Curve I

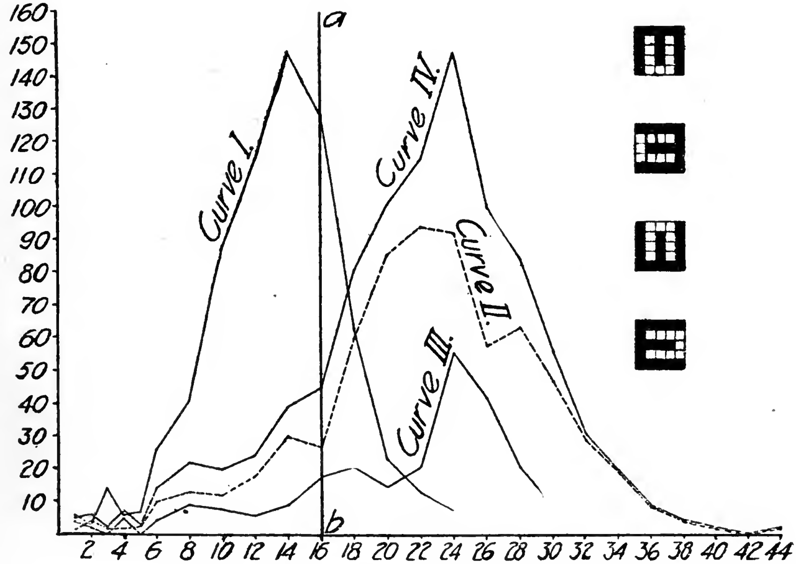
The distance in feet at which the eyes of 470 pupils of the Centennial Grammar School, Trenton, N. J., distinguished the Snellen Alphabet and Illiterate Cards.

Feet.	Grade VIII		Grade VII.		Grade VI.		Grade V.		Grade IV.		Grade III.		Totals. III.-VIII.		Gr. II.	Gr. I.	Totals I and II	Totals AllGrds.
	Alph.	Illit.	Alph.	Illit.	Alph.	Illit.	Alph.	Illit.	Alph.	Illit.	Alph.	Illit.	Alph.	Illit.	Illit.	Illit.	Illit.	Illit.
0																		
1	1	0	0	0	1	0	0	0	0	0	4	1	6	1	0	4	4	5
2	1	0	0	0	0	0	1	0	0	0	1	4	3	4	0	2	2	6
3	6	1	4	0	0	1	1	0	0	0	3	0	14	2	0	0	0	2
4	2	1	0	1	3	0	1	0	0	0	0	0	6	2	2	3	5	7
5	0	0	4	0	0	0	1	1	0	0	2	2	7	3	0	0	0	3
6	4	5	7	3	2	1	5	0	1	0	7	1	26	10	3	1	4	14
8	5	6	20	4	1	0	0	1	9	1	7	1	42	13	3	6	9	22
10	5	1	39	2	2	3	7	1	11	1	23	4	87	12	4	4	8	20
12	26	2	46	10	6	1	12	4	7	0	17	1	114	18	3	3	6	24
14	43	2	54	21	12	0	22	0	10	2	7	5	148	30	6	3	9	39
16	34	3	45	13	15	2	23	3	10	2	1	4	128	27	11	7	18	45
18	14	17	23	24	8	1	6	4	6	9	6	5	63	60	5	16	21	81
20	3	25	12	40	3	4	3	1	2	7	0	9	23	86	7	8	15	101
22	4	25	4	41	5	1	0	8	0	9	0	10	13	94	10	11	21	115
24	6	28	2	38	0	4	0	4	0	5	0	13	8	92	18	38	56	148
26	0	18	0	21	0	8	0	5	0	1	0	5	0	58	24	18	42	100
28	0	6	0	24	0	2	0	18	0	7	0	6	0	63	6	15	21	84
30	0	1	8	0	0	7	0	20	0	5	0	6	0	47	4	5	9	56
32	0	4	0	6	0	9	0	6	0	3	0	1	0	29	2	0	2	31
34	0	3	0	4	0	4	0	5	0	4	0	0	0	20	0	0	0	20
36	0	6	0	0	0	2	0	1	0	0	0	0	0	9	0	0	0	9
38	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	0	0	4
40	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2
													CURVE I.	CURVE II.			CURVE III.	CURVE IV.
Total No. of Eyes	154	154	260	260	58	58	82	82	56	56	78	78	688	688	108	144	252	940

TABLE I.

represents the results of the alphabet test and Curve II represents the results of the "illiterate E" test.

The pupils of the first and second grades, 126 in all, were tested with the "illiterate E" only, because they did not all know the letters of the alphabet. Curve III represents the results obtained by testing these 252 eyes with the illiterate cards. Curve IV combines in a single curve the results of the illiterate test with the 470 pupils in all grades.



GRAPH 1.

The straight line a-b, running perpendicularly through the curves, is the line of assumed normal vision for all of the tests. If this were correct, then all of the eyes represented by the portion of the curves to the left of this line are subnormal, and all eyes represented by that portion of the curve to the right of the perpendicular are above normal in acuteness.

From these curves we deduce the following results:

	Eyes Normal	Eyes Subnormal
Curve I (alphabet test).........	128 or 18.6%	453 or 65.8%
Curve III ("illiterate E").......	27 or 3.9%	56 or 8.1%

	Eyes Above Normal
Curve I (alphabet test)	107 or 15.5%
Curve III ("illiterate E")	566 or 82.2%

It is evident at a glance, that something is wrong, either with the letters used or with the "illiterate E," since the results were obtained under exactly the same conditions. It is not possible for both results to be correct, because with the "illiterate E," 8.1 per cent. of the pupils tested were subnormal and 82.2 per cent. were above normal; whereas, with the alphabet test, 65.8 per cent. of the same pupils were found to be subnormal and only 15.5 per cent, above normal. The fact that only 3.9 per cent. of the pupils, according to the illiterate test, had normal vision, and only 8.1 per cent. were subnormal, would warrant the suspicion that something was wrong with the "illiterate E," as a reliable measure for acuteness of vision. A close analysis of this character will prove that the suspicion is well founded. The structure of the "E" is shown at the right of Graph I.

A pupil being tested with this character has only to determine in which one of the four directions up, down, right, or left, the opening of the character is directed, and this opening can always be pointed out by observing that this side of the E is always the lightest. Each of these characters, as before stated, is constructed in a square which is subdivided into twenty-five squares. The normal eye is supposed to be able to discern one of these small squares at the same distance at which the E, turned in different directions can be recognized. It will be observed that there are three of these small squares lying together unfilled on the open side of this character. Four of these small squares, arranged in the form of a square has twice the diameter of the small square and should be discerned at twice the distance or 32 feet. It would, therefore, be reasonable to suppose that these three unfilled squares lying one above the other should be seen at about three-quarters of that distance, or twenty-four feet. As a matter of fact, this is exactly the distance at which they were discerned by the largest number of the pupils of all grades.

This comparative test proves conclusively that sixteen feet is not the distance at which the normal eye can just

discern the "illiterate E." In fact, twenty-nine eyes were found, exhibiting normal vision with the alphabet test, that could interpret these characters at twice sixteen feet. Many could read them farther than thirty-two feet, in fact, two could do this at forty-four feet and one could make them out at fifty feet.

It is evident then, that if this character is to be used for testing the acuteness of vision, a new distance, at which the normal eye can just see it, must be determined or the size of the characters must be changed. Either or both of these changes can easily be deduced from the results obtained by these tests.

Assuming that sixteen feet is the distance at which the sixteen foot letter can just be made out, by the average normal eye, then, the same relative variation from this normal sixteen foot distance, would be found to obtain in any sized letter or characters used in a series of tests. For example, if a series of tests with the sixteen foot letter, should show that the eyes tested could see the letters at an average distance of only twelve feet, or one-fourth less than normal distance, and, if another series of tests, made on the same eyes with another set of letters of any given uniform size and structure, should show that they could be seen at twenty-four feet, then the distance, twenty-four feet, should vary as much from the normal distance, at which such letters should be seen, as twelve feet varies from sixteen feet, the normal distance at which the sixteen foot letters should be seen. It is evident that the distance twelve feet is one-fourth less than the normal distance sixteen feet, and, since the same relation must exist in the series of tests which showed that the average distance at which letters or characters could be seen was twenty-four feet, then this distance, twenty-four feet is one fourth less than, or three-fourths of the distance at which the normal eye can see these letters or characters. If twenty-four feet is three-fourths of this normal distance, then the distance at which the normal eye should see these letters or characters is, 4/3 of 24 ft., or 32 ft.

In the series of tests described above it was found that the average distance at which the 688 eyes could just see the sixteen foot letters was 13.7 ft., and the average distance at which the same 688 eyes could see the "illiterate E," at

the same time was 23.2 ft. The distance at which the normal eye can see the sixteen foot letters is 16/13.7 of the average distance at which the letters were seen. Since the same relations must exist between the normal distance at which the "illiterate E," can be seen and the average distance at which it was seen, we find this normal distance by taking 16/13.7 of 23.2/1 ft., the distance at which the "illiterate E" could be seen. This gives 26.4 ft., which is the distance at which the normal eye can see the "illiterate E" used in these tests, instead of sixteen feet as was given by Snellen.

If it is desired to change the size of the "illiterate E," so that it can just be read at sixteen feet, instead of changing the distance at which it can just be seen, this can be readily done by making it just 16/26.4 of the size used in these tests. As these tests clearly show, one or the other of these changes should be made if the "illiterate E" is to be used as a test.

The second part of the problem has as its object, as already stated, the determination of whether the Snellen 12 ft., or a 16 ft. letter, or a black dot whose diameter is one-fifth the greatest diameter of a Snellen 20 ft. letter, might not be as reliable tests for acuteness of vision as the tests made with the Snellen 20 ft., 30 ft., 40 ft., or 50 ft. letters.

The vision of 200 pupils in the fifth, sixth, seventh, and eighth grades of a public school were tested in arriving at a solution of the second part of the problem.

The following is a description of the method used in making these comparative tests:

The tests were made in a room about 90 ft. long, near one end of which was a window so situated as to give an excellent light, in which to exhibit the letters in making the tests. A chalk mark was placed on the floor at the point where the light was best. Measuring from this line, a chalk mark was placed on the floor every two feet for the entire remaining length of the room which was 84 ft. These marks were numbered as follows: the first line, made on the floor at the point of best light, was marked 0; the next line, two feet away, 2; the next line, 4; the next, 6, etc., up to 84. This gave a clear range of vision of 84 feet.

It was decided beforehand that the letters and dots should be exhibited one at a time and that each should be exposed to view not longer than two seconds.

As stated above, it was not possible to find test cards printed in clear type of the right dimensions, and, it was also impossible to use these test cards for testing pupils with the different sized letters without some of the letters being memorized, thus thwarting the purpose of the tests. To overcome these difficulties, it was found not only necessary to have new types constructed with the correct dimensions, according to the Snellen measurements, but to devise entirely new vision test cards. These cards serve the double purpose of allowing only one letter to be seen at a time, and rendering it impossible for anyone to remember the order of the letters, and, beside, the tests can be made with much greater ease, accuracy, and rapidity than can be done with the ordinary test cards.

A set of these new test cards consists of twelve square cards about 5 in. x 5 in., on which are printed forty-eight letters of four sizes, one letter of each size on each card, no two cards having the same letters on them. The different sized letters can be seen by the normal eye at 20 ft., 30 ft., 40 ft., and 50 ft., respectively. These four letters, on each card, are placed so that one appears one-half inch from each margin and equally distant from the sides. And they are printed in such a way that only the letter at the top of the card is in a position to be read when the card is held in an upright position.

A reduced copy of one of these cards is shown in Fig. 2.

The tests are made with these cards exactly as tests are made with the ordinary test cards, except that the operator holds the cards in his hand and exhibits one letter at a time, by taking the cards one at a time, from the back of the pack and placing them in front. Any one of the four sized letters may be used by simply giving the cards a quarter or a half turn in the hands. Any possibility of remembering the order of the letters may be prevented by now and then shuffling the cards. This makes it possible to test pupils in their own rooms and in the presence of all the pupils if desired, and obtain trustworthy results.

In making tests with the black dots which were supposed to be seen at 20 ft., the first thing to consider was the

Figure 2. Showing the four sizes of letters and their arrangement on one of the twelve cards used in these tests. The smallest of these letters can be seen by the normal eye at 20 ft.; the next larger, 30 ft.; the next larger, 40 ft.; and the largest, 50 ft.

size of the dot. According to the rule laid down by Snellen, the normal eye can just discern an object whose largest diameter is one-fifth of that of a letter which can just be discerned at the same distance. A letter to be just discerned at 20 ft. should be 0.349 inches in height or in the largest diameter, so, the size of the dot to be seen at 20 ft., should be one-fifth of 0.349 inches or 0.0695 inches in diameter. Accordingly, a dot as nearly this dimension as possible was carefully constructed.

To enable one to make tests with the dot rapidly and to add interest to the work, another set of test cards was devised embodying the following, somewhat novel features, as shown in Fig. 3, Fig. 4, Fig. 5, and Fig. 6.

It takes ten of these cards to make a set. The dot in the ring is the object to be seen. There are three cards with the dot in the boy's ring; three with the dot in the girl's ring; three with the dot in the bear's ring; and one with no dot in either ring. All of the dots are identical in size.

The boy, girl, and bear are supposed to be playing ball, and each player is supposed to be trying to catch the ball in his racket. The dot is the ball and the rings are rackets.

The tests were made in this way: The pupil to be tested was placed at the distance where the normal eye can just see the dot. The operator shuffled the cards and then held them up face toward the pupil. As the cards were taken from the back of the pack and placed in front, the pupil was required to tell which had the ball, by saying "boy," "bear," etc., or, if he did not see the dot at all, by saying "nobody has it." This method, was found to have the great advantage of being easily understood by children and interesting to them. Even pupils in the kindergarten may be tested with these cards used as a game.

Having determined the kind of tests to be used and selected the position for the best light in which to exhibit the tests, and having marked off the floor as in making the tests with the "illiterate E" and the 16 ft. letters, and having swung a pendulum to beat seconds, the testing proceeded as follows:

An assistant took a set of the alphabet test cards and holding them in front of him in his two hands, took a card from the back and put it in front every two seconds, accord-

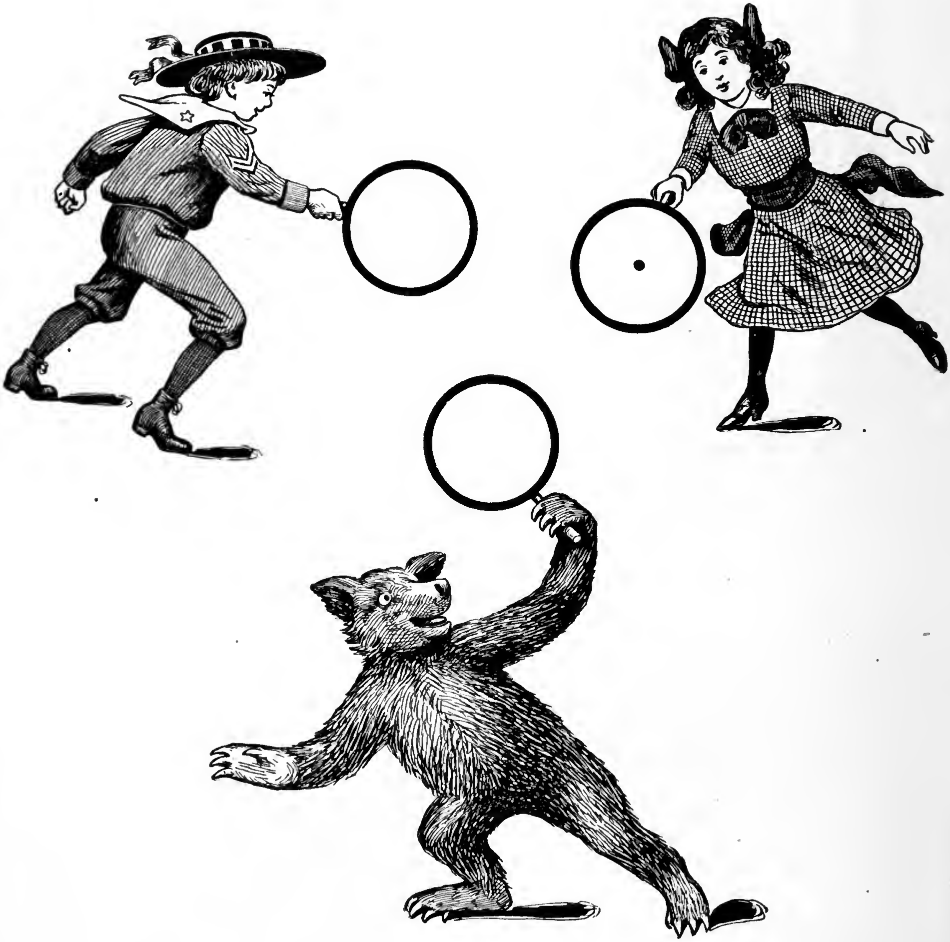


Figure 3. Dot test for acuteness of vision showing one position of the dot.

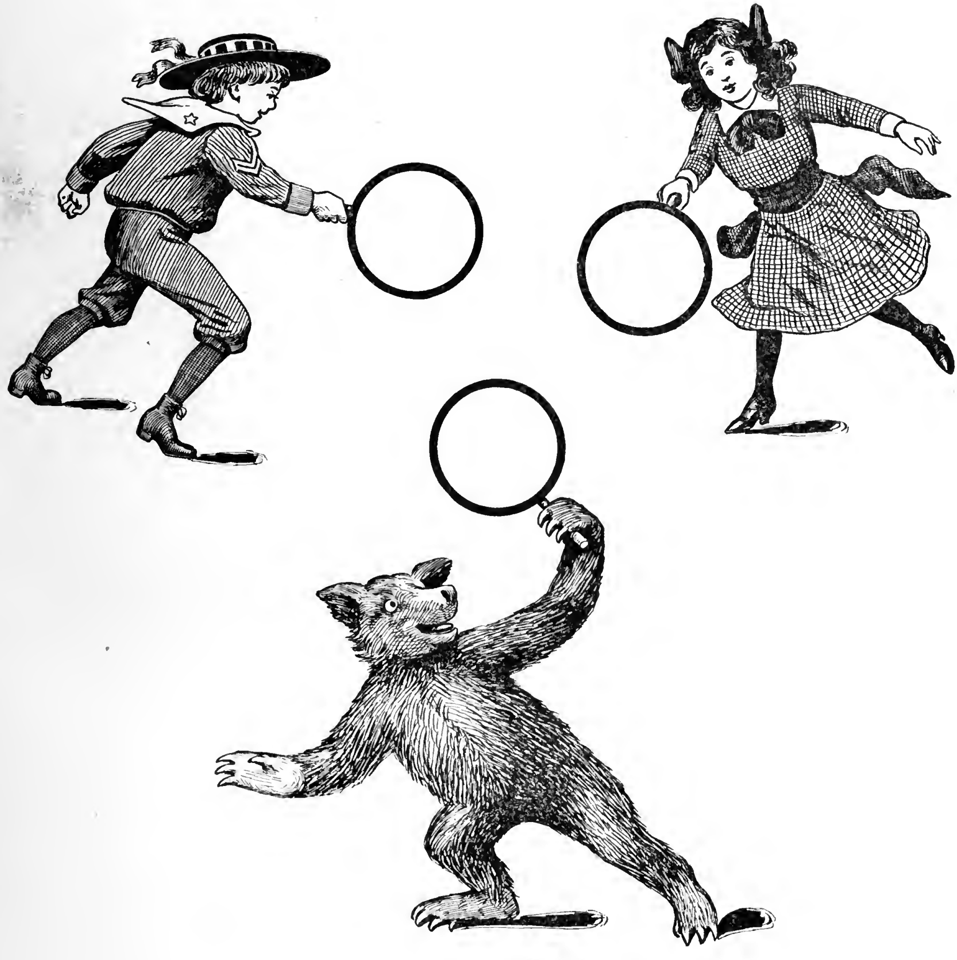


Figure 4. Dot test for acuteness of vision showing absence of dot.

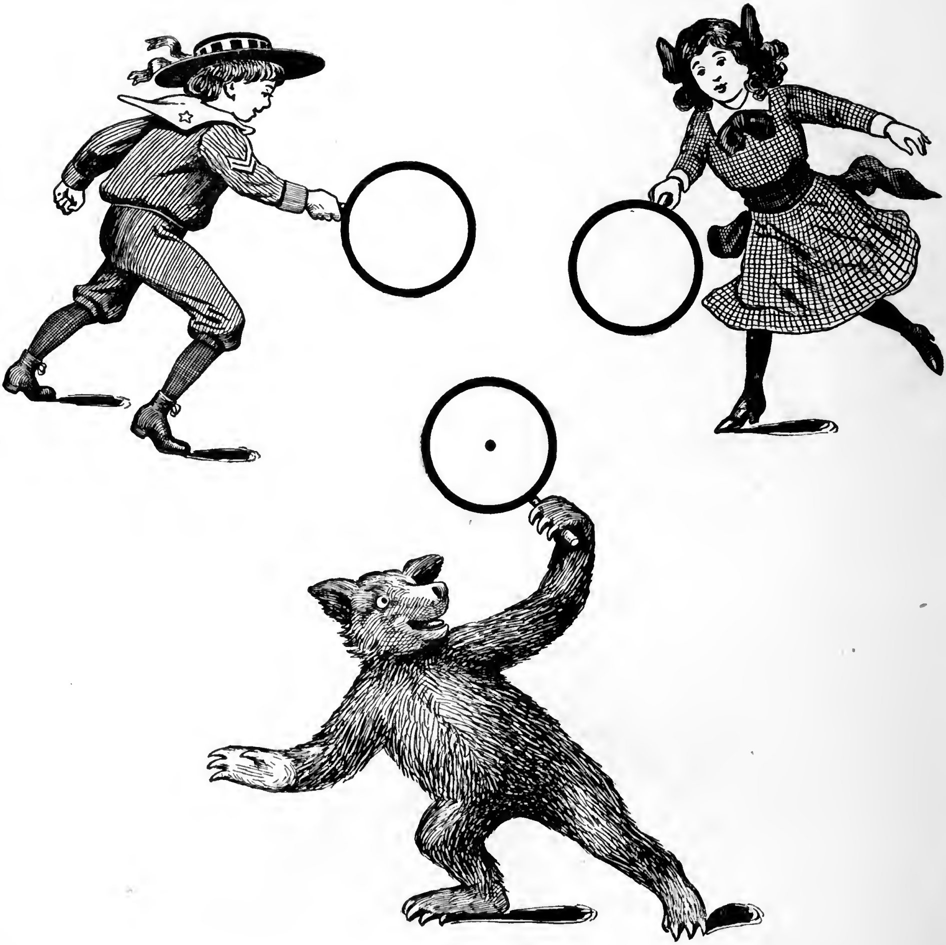


Figure 5. Dot test for acuteness of vision showing a second position of the dot.

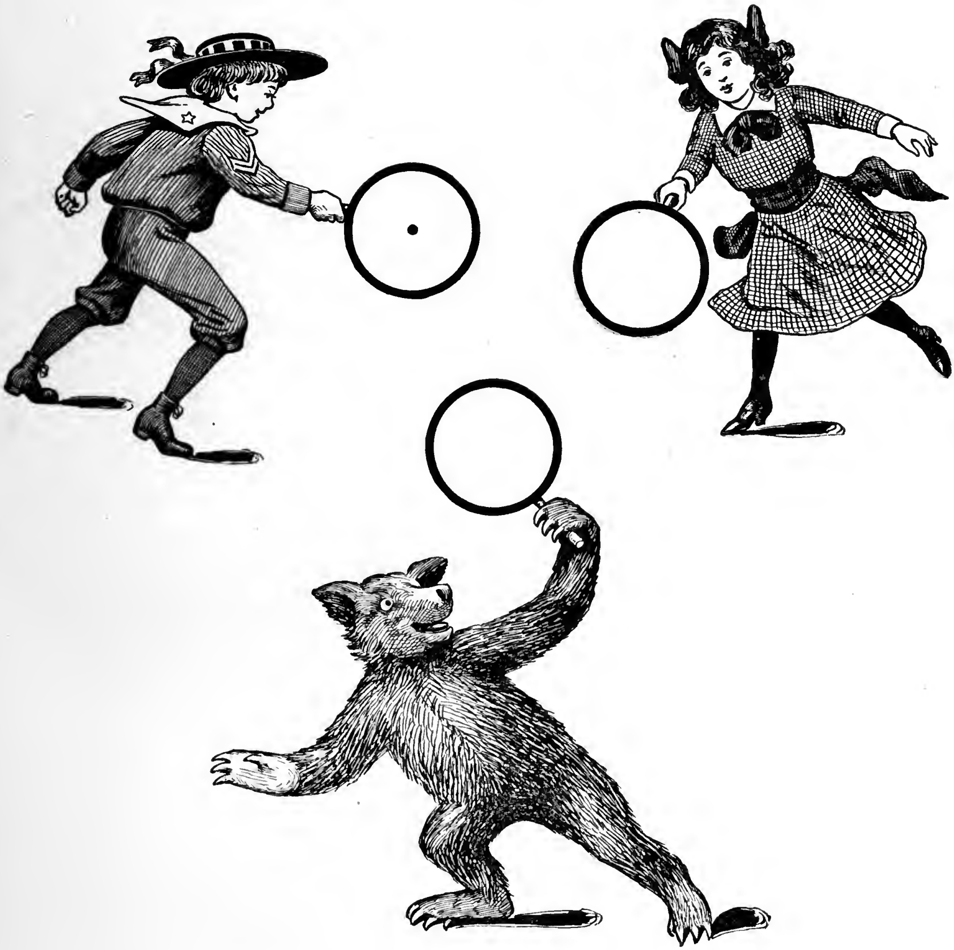


Figure 6. Dot test for acuteness of vision showing a third position of the dot.

ing to the beat of the pendulum. The cards were required to be held in the proper position to receive the best light.

The operator then, instructing the assistant to show the fifty foot letters, placed the subject with his toes to some mark beyond the fifty foot mark, say 60 ft., and required him, with both eyes open, to name the letters as they were presented by the assistant. If he could not correctly name five letters consecutively, he was instructed to move up two feet and try again. If he still failed to name correctly, the five letters consecutively, he was required to move up two feet more and try again, and so on, until a position was found where he could read the required number of letters consecutively. If it was found that the subject could read with ease all the letters while on the 60 ft. line, then he was required to move back two or more feet at a time until a position was found, where; at least five consecutive letters could just be read. When it was evident to the operator that mistakes were due to inattention or other causes than inability to see, another trial was allowed.

After the distance at which the 50 ft. letters could just be seen was found, the distances at which the 30 ft. and 20 ft. letters could just be seen was determined in the same manner.

The determination, at which the 20 ft. dot could just be seen followed the test with the 20 ft. letters, and was carried out in this way: The operator held in his hands the set of ten cards, described above, and presented them in the same manner as in making tests with the cards containing the alphabet. However, as none of the pupils understood what they were to do in this test, the method was explained to each pupil or several at a time by showing them the cards by saying, "Pupils the boy, girl, and bear are playing a game of ball. The dot is the ball. As each new card is presented the dot changes position from the ring or racket of any one of the players to either of the other two players, or the one having the ball may keep it through one or more changes. As in a real game, the ball may be lost, so, in this game, and the lost ball is indicated by a card being presented on which no ring contains a dot. Now, you are to be the umpire of the game and your duty will be to tell who has the ball as the cards are changed." A few cards were then presented and the pupils were required to tell who had

the ball. When the game was understood, the pupil to be tested was told to stand at the 16 ft. or 18 ft. line and try seeing the dot a few times. After he saw it at this distance he was required to move back two or more feet at a time and try again, and so on, until a distance was found, at which, the dots or blanks on five consecutive cards could just be made out. This distance was recorded as the distance at which the dot could just be seen.

When through testing with the 20 ft. dot, the subject was then tested with the 16 ft. letter and then with the 12 ft. letter, exactly in the same manner as the tests were made with the 50 ft., 40 ft., 30 ft., and 20 ft., letters. In passing pupils through each of these seven tests consecutively, it was found that results were often modified by the eyes becoming fatigued. When this was found to be the case, the subject was allowed to rest for a short while.

Realizing that fatigue might modify results if each one of the 200 pupils were tested first with the 50 ft. letter, then the 40 ft. and so on, down to the 12 ft. letter, every other pupil began his test with the 12 ft. letter, then took the 16 ft. letter, then the 20 ft. letter and so on, up to the 50 ft. letter. By this method it can readily be seen that, whatever effects fatigue might produce, this effect would be equally distributed, and consequently, it would be non-effective, so far as the purpose of these tests is concerned.

These tests were conducted for each pupil in the same room, and with the same kind of daylight as far as possible. Care was taken not to make tests on cloudy or dark days.

Since the purpose of these tests was to find out how far each pupil could see the different sized letters and the dot, or how acute vision was, the pupils were allowed to use both eyes at once. This was done because looking with the two eyes is the normal way of seeing things, consequently, it is believed that the results obtained more nearly represent the true acuteness of vision of the pupils tested, than if each eye had been tested separately. Pupils wearing glasses were tested with their glasses on.

Tables 2, 3, 4, 5, 6, 7 and 8, pages 23-27, show in detail one phase of the results of these tests.

Column (A) gives the number of pupils who saw the dot or letters at the same greatest distance.

Column (B) hsows the greatest distances at which the different groups of pupils in column (A) could see the dot or letter.

Column (C) gives the combined distances at which the groups of pupils in (A) could see the dot or different sized letters.

In each of these tables the sum of column (A) equals 200, the total number of pupils tested. The sum of column (C) in each table equals the total combined distance at which all of the 200 pupils could see the letters or dot used in the test. Therefore, it is evident that if these total combined distances in each table were divided by 200, the number of pupils tested, the result will be the average greatest distance at which these pupils could see the letters or dots with which they were being tested. The performance of this operation gives the following results:

The total combined distance at which the 200 pupils saw the 50 ft. letters is 10,894 ft. This divided by 200 gives 54.47 ft. as the average distance at which the 50 ft. letters were seen.

Table 2.

Results obtained by the tests made with the 50 ft. letter:

(A)	(B)	(C)
3	82	246
1	80	80
1	78	78
4	76	304
1	74	74
3	72	216
6	70	420
—	—	—
19		1418
—	—	—
7	68	476
13	66	858
10	64	640
10	62	620
16	60	960
—	—	—
56		3554
—	—	—
15	58	870
13	56	728
18	54	972
14	52	728
17	50	850
—	—	—
77		4148
—	—	—
12	48	576
1	46	46
7	44	308
3	42	126
1	40	40
—	—	—
24		1096
—	—	—

(A)	(B)	(C)
3	38	114
2	36	72
6	34	204
3	32	96
0	30	00
—	—	—
14		486
—	—	—
1	28	28
0	26	00
3	24	72
1	22	22
1	20	20
—	—	—
6		142
—	—	—
—	—	—
1	18	18
0	16	00
1	14	14
0	12	00
1	10	10
1	8	8
—	—	—
4		50
—	—	—
200		10894 ft.

Average distance: 54.5 ft.

Table 3.

Results obtained by tests made with the 40 ft. letters:

(A)	(B)	(C)
1	74	74
1	72	72
0	70	00
0	68	00
0	66	00
0	64	00
5	62	310
3	60	180
10		636
3	58	174
8	56	448
8	54	432
9	52	468
11	50	550
39		2072
21	48	1008
14	46	644
19	44	836
20	42	840
30	40	1200
104		4528
10	38	380
5	36	180
4	34	136
4	32	128
6	30	180
29		1004

(A)	(B)	(C)
5	28	140
3	26	78
2	24	48
2	22	44
0	20	00
12		310
0	18	00
2	16	32
0	14	00
1	12	12
1	10	10
1	8	8
0	6	0
0	4	0
1	3	3
6		65
200		8625 ft.

Average distance: 43.13 ft.

Table 4.

Results obtained by tests made with the 30 ft. letters:

(A)	(B)	(C)
1	60	60
1	58	58
1	56	56
0	54	00
0	52	00
0	50	00
3		174
4	48	192
5	46	230
8	44	352
9	42	378
10	40	400
36		1552
14	38	532
20	36	720
26	34	884
19	32	608
24	30	720
103		3464
16	28	448
10	26	260
10	24	240
6	22	132
6	20	120
48		1200
2	18	36
1	16	16
2	14	28
0	12	00
2	10	20
0	8	00
2	6	12
0	4	00
1	3	3
10		115
200		6705 ft.

Average distance 33.5 ft.

Table 5.

Results obtained by making tests with the 20 ft. letters:

(A)	(B)	(C)
4	34	136
7	32	224
6	30	180
17		540
19	28	532
21	26	546
31	24	744
35	22	770
38	20	760
144		3352
12	18	216
11	16	176
7	14	98
3	12	36
2	10	20
1	8	8
3	6	18
39		572
200		4438 ft.

Average distance: 22.2 ft.

Table 6.

Results obtained by making tests with the 20 ft. dots:

(A)	(B)	(C)
1	34	34
2	32	64
5	30	150
8		248
12	28	336
11	26	286
30	24	720
45	22	990
37	20	740
135		3072
25	18	450
12	16	192
8	14	112
3	12	36
4	10	40
1	8	8
3	6	18
0	4	0
1	2	2
57		858
200		4178 ft.

Average distance: 20.9 ft.

TABLE 7.

Results obtained by making tests with the 16 ft. letters:

(A)	(B)	(C)
2	28	56
1	26	26
4	24	96
18	22	396
29	20	580
54		1154
59	18	1062
34	16	544
30	14	420
9	12	108
6	10	60
4	8	32
2	6	12
1	4	4
1	3	3
146		2245
200		3399 ft.

Average distance: 16.9 ft.

TABLE 8.

Results obtained by making tests with the 12 ft. letters:

(A)	(B)	(C)
12	18	216
36	16	576
47	14	658
50	12	600
145		2050
23	10	230
21	8	168
5	6	30
3	4	12
2	2	4
1	1	1
55		445
200		2495 ft.

Average distance: 12.5 ft.

The combined distance at which the 12 ft. letters could be seen was 2,495 ft. This divided by 200, equals 12.48 ft., the average distance at which the 12 ft. letters were seen.

Putting these results in tabular form we have:

TABLE 9

Average distance at which

50 ft. letters could be seen	54.47 ft.
40 ft. ” ” ” ”	43.13 ft.
30 ft. ” ” ” ”	33.5 ft.
20 ft. ” ” ” ”	22.2 ft.
20 ft. dots ” ” ”	20.9 ft.
16 ft. letters ” ” ”	16.94 ft.
12 ft. ” ” ” ”	12.48 ft.

If each one of these different sized letters and the dot has the same value in making tests, then the fraction expressing the acuteness of vision as shown by the 50 ft. letter test will be equal in value to the fraction representing the acuteness of vision as shown by the tests made by the 40 ft. letter, the 30 ft. letter, and so on, to the fraction representing the acuteness of vision as shown by the 12 ft. letter test. In other words, the fractions representing the acuteness of vision as shown by making tests with each of the different sized letters and the dots will be equal in value.

How nearly this proved to be true with the tests under consideration is shown in Table 10. The first fraction was obtained by adding the numerators of each of the 200 fractions representing the acuteness of vision, as shown by each test with the 50 ft. letter, and placing this sum over the sum of all the denominators, which of course, was, in this case, 200x50, because there was a fraction for each of the 200 pupils tested and the denominator representing the acuteness of vision was always 50.

The second and all the other fractions were obtained in exactly the same way, except that the denominators of the respective fractions were obtained by multiplying 200 by 40, 30, 20, etc.

TABLE 10

Fractions showing the acuteness of vision of 200 pupils when tested by the

50 ft. letters	$\frac{10894}{10000}$	or	expressed	decimally	1.089
40 ft. "	$\frac{8625}{8000}$	"	"	"	1.077
30 ft. "	$\frac{6705}{6000}$	"	"	"	1.118
20 ft. "	$\frac{4474}{4000}$	"	"	"	1.119
20 ft. dots	$\frac{4186}{4000}$	"	"	"	1.046
16 ft. letters	$\frac{3387}{3200}$	"	"	"	1.056
12 ft. "	$\frac{2495}{2400}$	"	"	"	1.04

Of course, if each of the 200 pupils had tested up to normal with each kind of test the fractions would not only have been equal in value but each would have been equal to one or unity. The decimal parts of the numbers in the column to the right show just how much each test is away from the normal. Thus the first decimal .089 means that tests made with the 50 ft. letters averaged .089 of 50 ft. above normal or 4.45 ft. The next decimal .077 means that tests made with the 40 ft. letter yield results .077 of 40 ft. or 3 ft. above normal, etc.

If we take the decimal .077 which shows the variation of the results obtained by the 40 ft. letter test, as the mean variation, then the variation of each of the other decimals from this mean would give a result so small that it could be neglected in any ordinary tests for acuteness of vision with any of the letters or dots.

These fractions not only show that the amount of variation of each kind of test from the mean variation is slight, but that all of these variations are uniformly above normal.

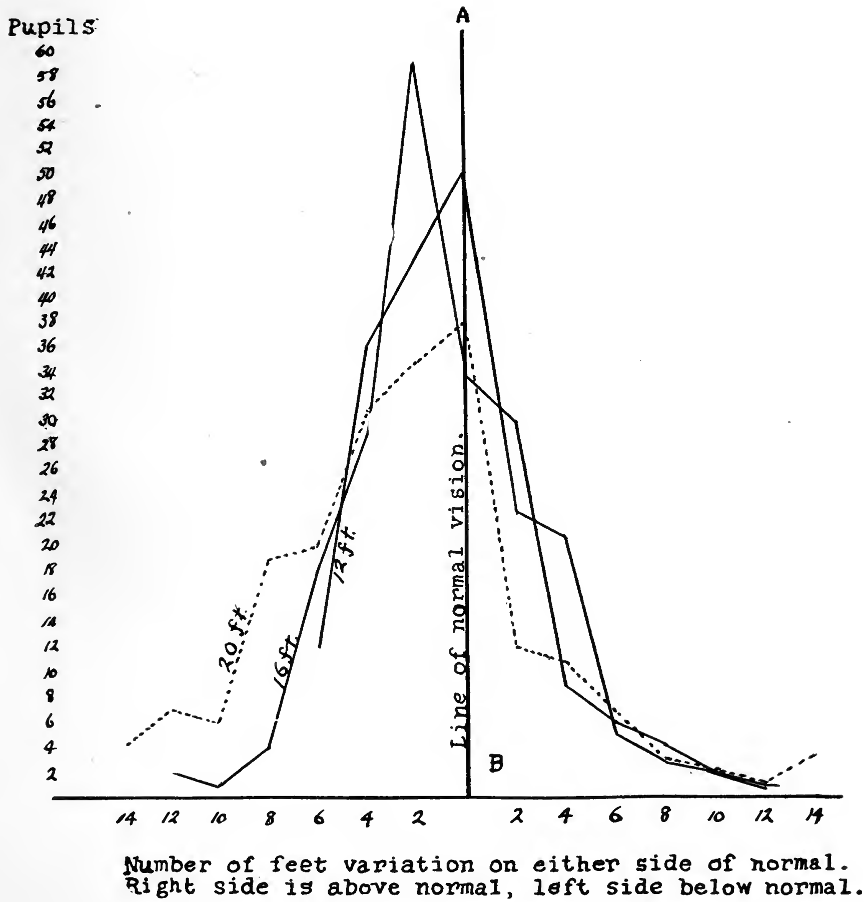
The fact that each one of these tests shows but little variation from the normal or from the mean variation does not, within itself, necessarily mean that each is equally valuable for making tests of acuteness of vision. Grave errors may exist of a plus and a minus nature, but of magnitude so nearly equal as not to be disclosed by mere averages.

The exact location and the exact extent of these variations from the assumed normal is shown in tables 2 to 8. A glance at these tables shows at once the number of pupils (column A), who could see the different tests at different distances. These same facts are graphically represented in graphs 4, 5, and 6. These graphs not only represent the number and extent of the variation from the normal, but graph 4 shows the variation of these in the 12 ft., 16 ft., and 20 ft. letter tests both from the normal and from each other. Graph 5 shows the same facts in reference to the 20 ft. letter test and the 20 ft. dot test. Graph 6 shows these facts in reference to tests made with the 30 ft., 40 ft., and 50 ft. letter tests.

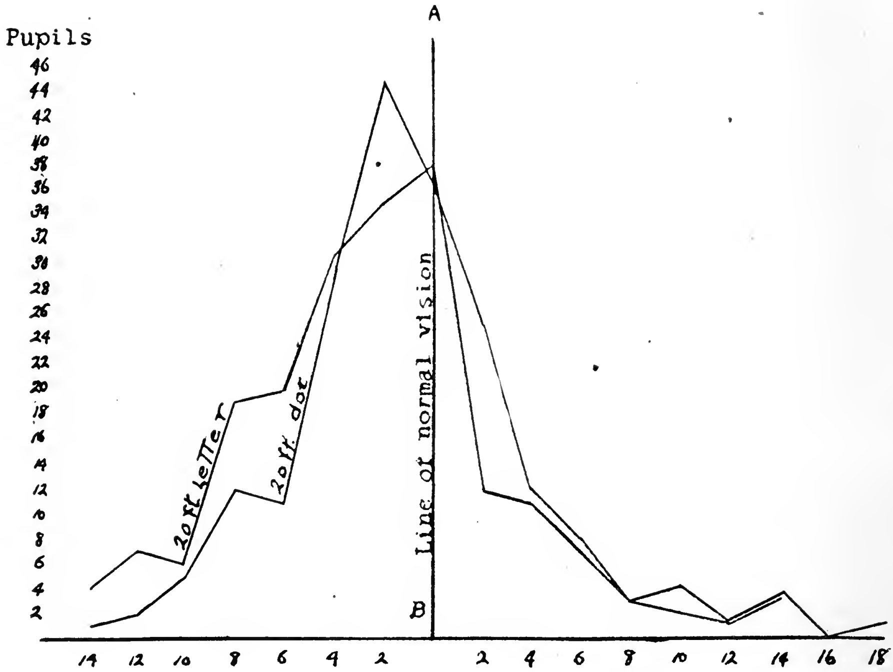
In each one of the graphs the line a-b represents the assumed distance at which the normal eye could just make out the letters or dots.

The vertical column of numbers at the left represents the number of pupils who could see the tests at the different distances.

The horizontal line of figures beneath the curves increases by two's, both right and left, beginning at the base of the line a-b, and shows the number of feet variation from the normal, a-b, made by each group of pupils, indicated by the vertical line of figures at the left. The figures to the left of the base of line a-b represent the distance above normal and the figures to the right, the distance below normal.

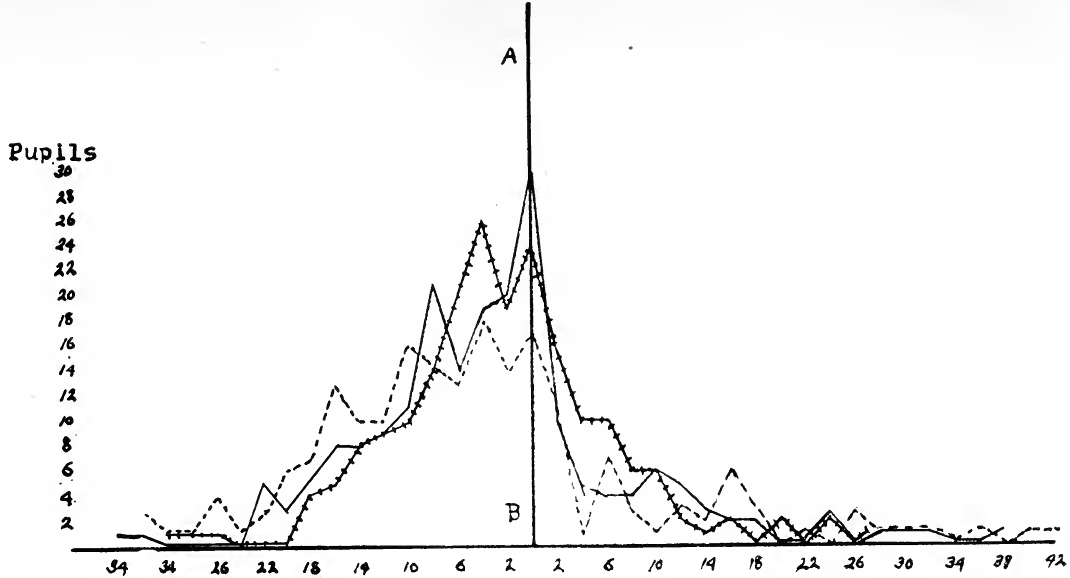

Pupils
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
A
B
Line of normal vision.
20 ft.
16 ft.
12 ft.
14 12 10 8 6 4 2 2 4 6 8 10 12 14
Number of feet variation on either side of normal.
Right side is above normal, left side below normal.

Graph 4.



Number of feet variation on either side of normal.
Right side is above normal. left below.

GRAPH 5.



Number of feet variation on either side of normal.
Right side is above normal, left side below normal.
.... line, 50 ft. letters
+++++++ crossed line, 30 ft. letters
——— straight line, 40 ft. letters

Graph 6.

If all of these seven tests had been of equal value in testing normal vision and those above and below normal, and, if the curves representing these results had all been placed in one figure, then the apexes of each of these curves would either have been on the line a-b or some other line parallel to line a-b.

Furthermore, the curve representing the results obtained by testing with the 50 ft. letters would have its apex higher than any other curve and the distance between the two ends of the curves would be greater than the distance between the ends of any of the other curves. Immediately under this curve with its apex on the same vertical line with the apex of the 50 ft. curve and with its two ends less distance apart would come the 40 ft. curve. Then would follow the 30 ft., 20 ft., 16 ft. and 12 ft. curves in order, each being not so high or wide as its predecessor and the sides of each would be parallel with the 50 ft. curve, and, of course, with each other, also.

The curve for the 20 ft. letters and the curve for the 20 ft. dots, theoretically, should be the same, and, of course, would be represented by one and the same curve, if placed in the same graph.

It was found impractical to put all of these curves in one graph, so they are shown in three graphs: 4, 5 and 6.

A glance at these graphs shows at once that no two curves are parallel and, consequently, the results of no two tests are uniform. As a matter of fact, no two such curves will ever be parallel, even if the tests used were of equal value as tests, for the personal element, of both the operator and the subject, and the influence of environment are constantly injecting themselves into and modifying the results, consequently, variations of these curves from each other are to be expected within certain limits. We can prescribe these limits, however, and require that results from tests obtained by using any size letter and character shall come within these limits.

It would be fair, it seems, in making tests with different sized letters and characters to expect that the numbers who could see these letters and characters further than 12½% of the selected normal distance should be fairly constant.

The same requirement might be made for the lower limit of vision with these same tests. That is, the number un-

able to see each test without moving nearer to the test than 12½% of the selected normal distance should be fairly constant.

If this limit were not broad enough then any percentage of the normal distance above or below the normal greater than 12½% might be taken, as 25%, 37%, or 50%, and we could require that the number seeing the different tests further than normal by these percentages should be fairly constant, and, that the number who could not see the same tests without getting nearer to them than the percentages of the normal distance indicated, should also, be fairly constant. Both of these methods of determining whether a test is reliable or not has value. If it is desirable to determine how acute the vision of a pupil is who has acute vision, then the upper limit method of trying out the tests will be of value. If, however, it is desired to know how acute the vision of a pupil is who cannot see the test as far away as the normal distance, then the lower limit method will be of value. But, since most pupils are supposed to have somewhere near normal vision, it would seem, if the correct tests are used, that the number seeing these tests at normal and a certain percentage above and below the normal distance should be fairly constant, for all the tests. This might be called the mean limit of tests for acuteness of vision. These methods of determining the relative value of testts have been used in connection with the seven different tests under consideration and the results are shown in table 11.

The (a) portion of this table represents the results obtained by applying what has been called the "upper limit test," for the given percentages above normal, to the results obtained from each of the seven tests.

In (b) is shown the result of applying the "lower limit test," with the same percentages, to the results of the same tests.

In (c), is shown the results of applying the "mean limit test," with the same percentages, to the results of the same tests. The uniformity of the results shown in (b) by applying the "lower limit test" is quite striking in the 12½% line except the numbers under the 16 ft. and the 12 ft. letters and a close degree of uniformity in all the tests, is also seen in the 25%, 37½%, and 50% lines, respectively.

This table shows the number of pupils who could see the lettrs and dots at different percentages of the distance at which they were supposed to be seen by the normal eye.

		50 ft. Letters	40 ft. Letters	30 ft. Letters	20 ft. Letters	20 ft. Dot	16 ft. Letters	12 ft. Letters
A	No. seeing further than normal by 12½%	90	70	83	72	61	54	71
	25%	49	38	39	46	31	25	48
	37½%	19	13	20	17	8	7	12
	50%	5	7	7	11	3	3	0
B	No. seeing less than normal by 12½%	28	32	32	32	32	23	44
	25%	21	18	16	16	20	14	21
	37½%	10	8	8	9	12	8	8
	50%	6	6	5	4	5	4	6
C	No. seeing at normal and on either side of normal to 12½%	90	98	85	96	117	106	85
	25%	130	144	145	138	149	161	147
	37½%	171	179	172	174	180	185	186
	50%	189	187	188	185	188	193	194

TABLE 11.

According to these figures, either one of the tests except the 12 ft. letter test could be relied upon to detect vision, that is less than 50% of normal, or 37½% or 25% or even 12½% of normal. Since the detection of poor vision, rather than the determination of how many have acute vision, above normal, is the chief purpose of testing the vision of school children, any of the seven tests under consideration except the 12 ft. letter test would be adequate for this purpose, especially is this true, if, as is usually the case, only those pupils who have vision less than 25% normal are given attention.

By inspection of the (c) portion of table 11 or that portion showing the mean variation from the normal, we see here, too, a rather close degree of uniformity of results. This is especially marked in the figures showing variations on both sides of the normal of more than 25%, and, it would seem reasonable to expect that any vision test that makes any pretension to reliability should show similar results when this test is applied.

If we now give our attention to the (a) portion of table 11, we see here, too, a rather close degree of uniformity in all the tests for the upper limit of vision for all the percentages taken above normal. Since the application of all of these tests to the tests under consideration give fairly uniform results, it is reasonable, it seems, to conclude that the results in general will be about as accurate with one test as with another. Exceptions, however, will have to be made with the 12 ft. letter tests, although the figures in the tables would seem to indicate that this test is generally about as good as any of the other tests. This exception will have to be made in spite of these figures, because in at least two cases of undoubted nearsightedness, the pupils could not see the larger letters at anything like the normal distance, but they could see the 12 ft. letters at about normal.

The variation of results of certain tests from the results of other tests as shown in table 11 demands some attention.

In the (a) portion of the table it is noted that the number seeing the 20 ft. dots beyond the normal distance by the different given percentages is smaller in every case than with any of the other tests except the 16 ft. letter. From the data obtained from these tests it is not possible to as-

sign a reason why the 16 ft. letters were not seen as far proportionately above the normal as were the twenty ft. letters or any of the other letters, but it is believed that the failure to see the 20 ft. dots as far as the letters, can be accounted for in this way. In deciding what a letter is, the element of intelligence as well as the ability to see enters in as a determining factor much oftener than is the case with deciding whether the dot is seen or not.

In seeing the dot only two things can enter into the mind on which a decision is to be made, and these two things are, is the dot there, or is it not there, or does the dot make a sensation on the retina or does it not. The decision that is made will depend almost exclusively upon pure retinal sensation. While in the case of seeing the letter there can be no doubt that the letter is seen, that a retinal impression is made, but in deciding what the letter is that is making this particular impression, often, undoubtedly, involves a complicated mental operation, in which the general shape and appearance of the letter play a very important part. Hence, one must expect fewer pupils to see the 20 ft. dot at distances considerably above normal than will see the same sized letters or letters of any size at proportional distances.

This expectation is borne out by the figures in (b), table 11. Here it is seen that the dot shows up more pupils with defective vision, on the average than any of the letter tests, at the percentages below normal given, except the 12 ft. letter.

The figures in (c) under the 20 ft. dot column also show that the letters of all sizes above the 16 ft. letters can be seen better than the 20 ft. dot at the same relative distances. Take, for example, the 12½% variation on either side of normal, there were only 90 pupils who could not read the 50 ft. letters, while there were 117 who could not make out the dot at the same relative distance from normal. The fact that the vision of the 200 pupils tested averaged above normal and that more pupils saw the 20 ft. dots at the average distance above normal than for any of the other tests, and, since the number found with defective vision was unusually small, but the dot test showed more than any, one would be inclined to the belief that the dot is the best of any of the tests used. One would be justified in

coming to this conclusion, not only because it tests vision, and vision only, and the results are more in harmony with what other investigators have found out about the number of children who have defective vision, but, also, because of the simplicity of the test and the fact that it can be used to test little children, illiterates or literates with equal ease and accuracy. Further evidence that the dot is a good test is shown by the fact that there was not a single case of poor vision detected among the 200 pupils by any of the other tests that was not also detected by the dot test. This was also true with the tests made with the 16 ft. and the 12 ft. letter, except in the two cases mentioned above. This shows undoubtedly that for certain defects of the eye the 12 ft. letters are not reliable. The 16 ft. letters were found to be reliable for the detection of all cases of poor vision that would need attention and which were detected by the other tests.

The results of these tests clearly justify one in drawing the following conclusions:

1. The "illiterate E" as now constructed is practically useless as a test of the acuteness of vision. If it is to be used as a test when constructed of the size of the 16 ft. letter, then the distance at which it should be placed from the one being tested should be, not 16 ft., but 26 ft. Or, if the 16 ft. distance is to be maintained then the size of the letter must be reduced to 16/26 of its present size.

2. The 20 ft. dot test is thoroughly reliable for testing poor vision, normal vision, or acute vision. None of the 200 pupils tested seemed to have any optical trouble—myopia, hyperopia, astigmatism or any other optical defect—that was not detected by this test as well or better than by any other test.

3. The 16 ft. letter test is reliable for all defects of sufficient gravity to justify the teacher in recommending the pupil to go to an oculist.

4. The 12 ft. letter test will detect most of the graver defects of vision, but not all, therefore, it is not to be relied upon.

5. The eyes of 150 of the 200 pupils, subjected to these tests were tested, one eye at a time, a few weeks before.

Every pupil, with four exceptions, who had vision 25% or more below normal, as shown by this one-eye-at-a-time test, could with two eyes make a better showing. Not only was this true of pupils having poor vision, but it was equally true of all other pupils. This can be taken as an indication, not only, that binocular vision is better than monocular vision, but it accounts for the fact that the pupils in these tests averaged above normal in vision.